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WILLIAM MARKEY GEORGEN

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by

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Lieutenant Commander, United States Navy

Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE

United States Naval Postgraduate School
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ABSTRACT

Better methods have been developed recently to provide for the maintenance of a continuous inventory of U. S. Navy officer billets which require technical postgraduate education for the incumbents. The problem confronting the personnel planner is how to allocate quotas to the various postgraduate curricula when requirements are far in excess of personnel resources. A method is developed for determining the optimum number of officer inputs to individual postgraduate curricula, based on an assessment of long range utility to the Navy and the government. The method provides means for examining relative losses of utility to the government when quotas for a particular postgraduate curriculum must be reduced below the optimum due to limitations on personnel available for advanced education.

The author wishes to express his appreciation to Professor Charles C. Torrance and to Professor Thomas E. Oberbeck of the Department of Mathematics and Mechanics of the Naval Postgraduate School for their interest, encouragement and assistance in producing this paper.

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I

FORMULATION OF THE PROBLEM

1. Introduction

The application of Operations Analysis to the fields of education and personnel administration has lagged behind the application of analytic techniques to fields which are more susceptible to quantitative analysis. The reasons for the lag are manifest in the very nature of education and personnel administration. Values required to measure the effectiveness of various programs are difficult to define. Sheer numbers and the dollar sign are overshadowed as appropriate indicators by such difficult-to-measure items as human capability, the evaluation of performance, the requirements of a billet and its importance to the Navy, and the effectiveness of personnel detailing.

A number of studies of naval officer education [1] [2] have been conducted in recent years, and of postgraduate education in particular. These studies have produced recommendations, some of which are quite controversial. Others are being implemented. The exact future pattern of technical postgraduate education is uncertain at this writing. To attempt to analyze one segment of the overall problem in a period of changing concepts is difficult.

To establish a suitable framework for inquiry, the author feels compelled to make certain observations, state

certain opinions, and make some basic assumptions which he believes may fairly represent the future educational and personnel assignment pattern.

A sound basis for any inquiry into officer education is considered to be the concept that postgraduate education should be integrated with overall career planning [1]. This concept results in restrictions on the time of entry into postgraduate training, the length of such training, and the utilization of officers with technical postgraduate education. It has been determined that the best feasible time for an officer to embark on a technical postgraduate program is at the end of his fourth year of commissioned service. This conclusion apparently stems from a compromise on the part of the educators, who would like to commence training earlier than the fifth year of service, and the Navy's requirement for basic naval experience at sea. The conclusion is endorsed by the author, and in fact forms one of the bases for the analysis conducted in this paper. In the case of submarine and aviation officers, the nominal four year transition point is often lengthened. Normally, however, these officers can be expected to complete a postgraduate course while still in the Lieutenant rank. For purposes of this paper, the completion of four years service is considered to represent a prerequisite and restriction on entry into the technical postgraduate program.

Detailing considerations provide restrictions on the utilization of officers with postgraduate education. For engineering duty officers the problem is minimized in that officers are sequentially assigned duties making use of their specialty training. For unrestricted line officers the conflict between experience in a sub-specialty and preparation for command is present and restricts the utilization of unrestricted line officers. It is apparent, however, that better utilization of the unrestricted postgraduate line officer in the highly technical billets is a necessity of the times.

The "involuntary" selection system now in effect for the selection of officers to postgraduate training appears to be a psychological substitute for the previous "voluntary" selection system. Essentially, the criteria for selection appears to be similar to that previously used. The adoption of general one-year technical postgraduate courses [2], however, does not appear to the author as a reasonable course of action. Graduates of such a course, nominally the lower one-half of the total technical postgraduate input, cannot normally receive in one year sufficient advanced education to qualify them to fill most billets which require postgraduate educated incumbents. The training would therefore appear to be wasted, and the entire operation is an expensive substitution for closer selection of inputs to two , or more, year curricula based

on motivation, performance and qualification, whether or not they volunteered or were "involuntarily" selected.

Implicit in the author's general aversion to one-year technical postgraduate curricula is a rejection of the concept of some technical postgraduate training for all qualified regular officers [2] as being premature in light of present and immediate future requirements. The dilution of the Navy's overall educational effort by training many officers for short periods of time at the expense of sound specialty training for fewer officers does not appear to be a prudent procedure at this time, particularly when the need for officers takes priority over the possession of a baccalaureate degree by a sizable portion of newly commissioned officers. There are, and will continue to be for some time, a large number of billets which require no postgraduate education for their incumbents.

The problem as developed in this paper is essentially one of selecting the "best" number of Lieutenant quotas for a given postgraduate curriculum. Insofar as is known to the author, this task has been handled in the recent past by comparing declared billet requirements with the number of officer graduates qualified to fill them. A deficiency list, modified by appropriate scaling factors, would then serve as a basis for determining officer inputs to individual postgraduate curricula. The approach set forth herein considers the entire career time span of the postgraduate officer

after completion of advanced training. An attempt is made to provide for judging the relative value to the government of various numbers of individual curricula graduates completing a career billet sequence in their sub-specialties. The paper is oriented toward quota determinations for unrestricted line officers who will retain the 1100 and 1300 series designators. However, with minor model modification, the method proposed could be applied to those officers passing into restricted line or staff corps categories.

2. Objective

One of the many problems confronting the U. S. Navy today is the increasing demand for highly trained individuals generated by a rapidly increasing technical complexity. The satisfying of this demand is one of the immediate objectives of the Navy. The attainment of this objective, however, is complicated by many factors.

In the field of higher education, the method of pursuing the objective is tempered by influences both from within and from outside of the Navy. Within the Naval Establishment there are differences of opinion on the required type, priority, and length of postgraduate education, as well as on the utilization (e.g., specialists vs. line) of the education received. Imposed from without (and to some degree from within) the Navy are budgetary limitations and manpower ceilings.

Essentially, the Navy personnel planner in the field of higher education is currently faced with the problem of satisfying increasing demands with inadequate and sometimes shrinking resources. The goal, therefore, becomes the greatest satisfaction of demand within the framework of the limited resources available.

The demand for postgraduate educated officers now exceeds those available for postgraduate training. Obviously, any scheme for establishing optimum quotas for postgraduate curricula should provide some means for evaluating the effect of restricting quotas below the optimum to provide for the real life situation.

3. Measure of effectiveness

In order to select a solution to a problem, some means must be established for evaluating the worth of the available courses of action to the decision maker. Such a means for comparing alternative courses of action, in terms of the value of the outcome to the decision maker, may be called a measure of effectiveness of a course of action. The measure of effectiveness selected should reflect the aspect of the decision-making problem which is of prime importance to the person or agent making the decision. Dollar cost is of importance to most people, and is often used as a measure of effectiveness for comparing courses of action, but it need not be the quantity which is of paramount importance in making a decision.

In the problem at hand, it is considered appropriate to weigh the "value to the government" of various courses of action. The question which immediately comes to mind is: How are we going to measure a quantity which is vaguely described as "value to the government"? The answer is: By inventing a subjectively derived utility scale. Incorporating such a procedure into an analysis would have been frowned upon in the not too distant past. However, with the expansion of Operations Research into the psychophysical fields, and with renewed interest in what is now known as Utility Theory, such a procedure is often employed. The heart of the problem, of course, is in selecting an appropriate scale and in relating worth, value, utility or return to the government to numbers on this scale. This aspect is discussed in a later section of the paper.

An appropriate measure of effectiveness for selecting optimum quotas for individual postgraduate curricula is therefore considered to be the total worth to the government, over the career spans of the postgraduate officer inputs, expressed as a function of the number of officer inputs to an individual curriculum. The goal as expressed in the previous section then becomes the maximization of this total worth by selection of the optimum number of officer inputs to a curriculum.

II

CONSTRUCTION OF THE MODEL

1. General

It is often convenient to represent a situation or problem in a simplified form called a model. The model is then solved by appropriate computations and the solution transformed into action which will solve the real problem. Chernoff and Moses [3] regard a model as a useful, convenient, simplified representation of the essentially important aspects of a real situation. The determination of which aspects of the situation are relatively minor and may be omitted from the model is a matter of judgment for the model builder. Aspects considered important are retained in the model along with the important variable properties which influence the solution. The variables thus retained are often called parameters. Usually only a few of the many aspects of any natural phenomenon are incorporated in a model. Many aspects are neglected deliberately or by oversight, and those that are depicted may be ill chosen or ill defined.

If the model derived fairly represents the real life situation, an analysis of the model may produce solutions which may be applied successfully to the real life situation. In order to test the success of the model, the scientist will conduct experiments, if possible, to compare the

real life results with the model solution. In the present analysis, real life experiments are impractical because of the time span covered by the model. A statistical overview of the logic of the model solution has not been conducted because of the lack of current data on billet requirements for postgraduate educated officers in various sub-specialties. However, certain conclusions may be reached from interpretations of the model.

2. Assumptions

Many of the educational concepts embraced earlier in this paper as part of the framework for pointing up the problem constitute assumptions. They will not be reiterated here. Fundamental to the construction of the model, however, are three basic assumptions which will now be developed.

The first step in attacking a problem whose goal is the optimum fulfillment of demand is to determine the nature and extent of the demand. In the problem at hand, this constitutes determining the naval officer billets which should or must be filled by officers with specific postgraduate training. In the last few years the Chief of Naval Personnel has been perfecting the inventory of officer billets requiring postgraduate educated officers in various fields. The system as presently functioning should provide a fairly accurate summary of postgraduate requirements by rank, billet and curriculum. It should be noted, however,

that the human tendency to overstate requirements cannot be eliminated entirely, regardless of screening and follow-up controls.

ASSUMPTION: The present system of inventorying billets requiring postgraduate educated officers is accepted as a basis for determining optimum officer inputs to postgraduate curricula.

The second assumption relates to career patterns insofar as they affect sub-specialties. As previously stated, the purpose of postgraduate training is solely to fill the Navy's requirements for officers trained in certain specialty fields. Implicit in this purpose is the determination to utilize the officers so trained in billets requiring the specialty knowledge. Excluded from this objective are such marginal benefits as increased naval officer prestige through raising of the average education level, and providing incentives for career officer personnel. A high degree of utilization of postgraduate educated officers transferred to the Restricted Line and Staff Corps categories is inherent in the status of these officers, but not so in the case of line officers with designators in the 1100 and 1300 series.

ASSUMPTION: Unrestricted line officers will be utilized to the fullest extent possible in their sub-specialties generated by attendancein a postgraduate technical curriculum. For purposes of constructing a model, this utilization is assumed to average one tour per officer per rank in a billet connected with the sub-specialty.

The third basic assumption to be mentioned in this section concerns the existence of a utility function which is indicative of the worth to the government of each billet which requires a graduate of a particular postgraduate curriculum. More explicitly, we postulate the existence of a measurable quantity which represents value (satisfaction) to the government of filling a billet requirement with a qualified officer of the specified rank. We next modify the number which represents this utility for satisfying a particular rank-billet requirement in order to account for instances in which the billet cannot be filled properly, and instances in which there are more qualified officers than needed. In effect, we superimpose a utility function on the original utility index. This will be illustrated in the following sections. At this point the basic assumption will simply be stated as follows:

ASSUMPTION: There exists a measurable quantity which represents value (satisfaction) to the government for the various degrees of fulfilling billet requirements with qualified officers.

Of course, the selection of a scale and the assignment of numbers to represent value constitute assumptions, as does the use of a particular scale factor to convert the model solution to the real life solution. These factors will be developed in the following pages.

3. Utility measurement

Once the existence of a measurable quantity to represent value or utility is postulated, the problem becomes one of selecting a suitable measuring scale and mapping utility into this scale. A philosophical (and safe) approach is that if utility is to be measured, it should be measured on a scale at least as strong as a ratio scale.

A ratio scale is the most difficult scale to establish, but once established, it is the least restricted in usefulness. It is characterized by the kinds of transformations which may be applied and still leave the structure of the scale undistorted. Briefly, a ratio scale exists only when there exist operations for determining the following four relations: equality, rank order, equality of intervals, and equality of ratios (proportionality). All types of mathematical operations are applicable to ratio scales. Examples of such a scale are the scales upon which physical units such as length are based.

In placing the properties of numbers in correspondence with value or utility to the government, we can invoke empirical operations and considerations for determining equality, rank ordering, and for determining when differences and when ratios between various values are equal. Once the correspondence is empirically determined by the model builder, objections may be raised as to the accuracy or bias of the correspondence. One should remember, however, that

the agreement of measuring scale with value concepts is a practical matter and that there are always empirical errors of measurement no matter what the scale.

The following measuring ratio scale has been selected to represent relative values to the government of filling billet requirements in the various ranks with qualified officers. The units of value are simply utility units, or "utiles," to use a popular term. It may be observed that the utility to the government is essentially defined as a linear function of years of commissioned service with the zero point of the scale occurring at the zero point of commissioned service.

Utility units	Billet rank requirement
5	Captain
4	Commander
3	Lieutenant Commander
2	Lieutenant
1	Lieutenant (jg) & Ensign

4. Penalty functions

To provide a means for modifying utility to account for instances where billet requirements cannot be filled due to insufficient numbers of qualified officers, and for instances where more qualified officers in a particular rank are available than required, it is necessary to impose another utility function over the space of the utility index just derived.

This function, of necessity, is devised in a more arbitrary manner than the basic index and its final form should be examined with care.

The author has selected the following rules to be applied to each basic rank utility, reducing that quantity by various amounts to account for deviations from the ideal situation where requirements and resources are equal. If W represents the utility unit of the basic index corresponding to a satisfied billet-rank requirement, then -W represents the utility to the government of being unable to fill the billet-rank requirement due to insufficient numbers of qualified officers. Depending on rank, the penalty would take on the value -5, -4, -3, -2, or -1 per vacant billet.

If more postgraduate educated officers were on hand than needed in a particular rank, the surplus would represent a partially unrecovered investment on the part of the government. This lack of utilization is recognized by assigning a penalty of -W/2, where W is defined as indicated above. An "extra" trained officer in the Commander rank would generate a penalty of -2 utility units. The penalty is less severe than the penalty of -W for an unfilled billet-rank requirement because it may be assumed that some of the education received by the "surplus" trained officer may be put to use even though the actual billet that he fills does not require postgraduate education.

The view is widely held that a postgraduate educated officer should serve two tours of duty in his sub-specialty in order that the government be "paid back" for its investment in his education. Although this is a very general viewpoint, it seems appropriate to assign a heavier utility penalty to the case in which the "surplus" postgraduate educated officer in a particular rank probably will not have the opportunity to serve two tours of duty in his sub-specialty during a career time span. The invoking of the penalty, of course, depends on the distribution by rank of the billet requirements and the assumption that on the average an officer may expect to serve one tour of duty per rank in his sub-specialty. The heavier penalty to be assigned in the above case shall be -W.

III

INTERPRETATION OF THE MODEL

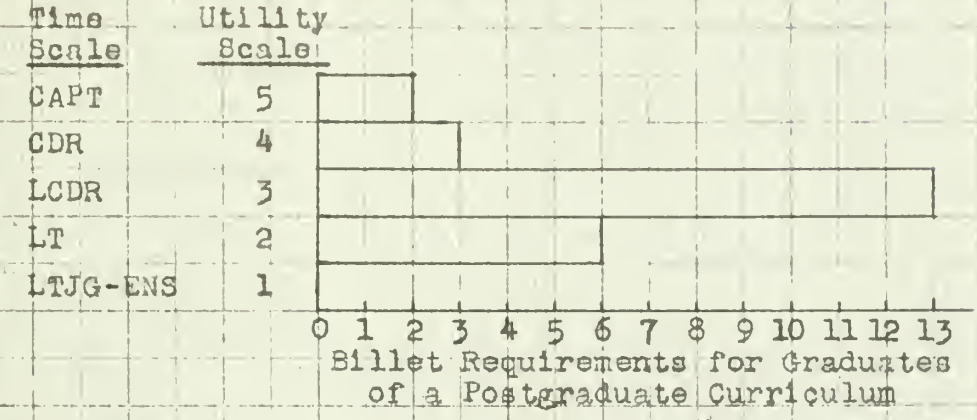
1. Solution of the model and application to the real problem

The foregoing chapters have formulated a problem and derived a model from which, it is hoped, a solution can be obtained which will correspond to a practical solution of the real life problem. A somewhat elaborate overall utility index has been constructed for the model and the problem has been simplified to one of selecting the number of officer inputs to a particular postgraduate curriculum which will maximize the utility index. Typically, this is a problem in decision making under conditions of certainty.

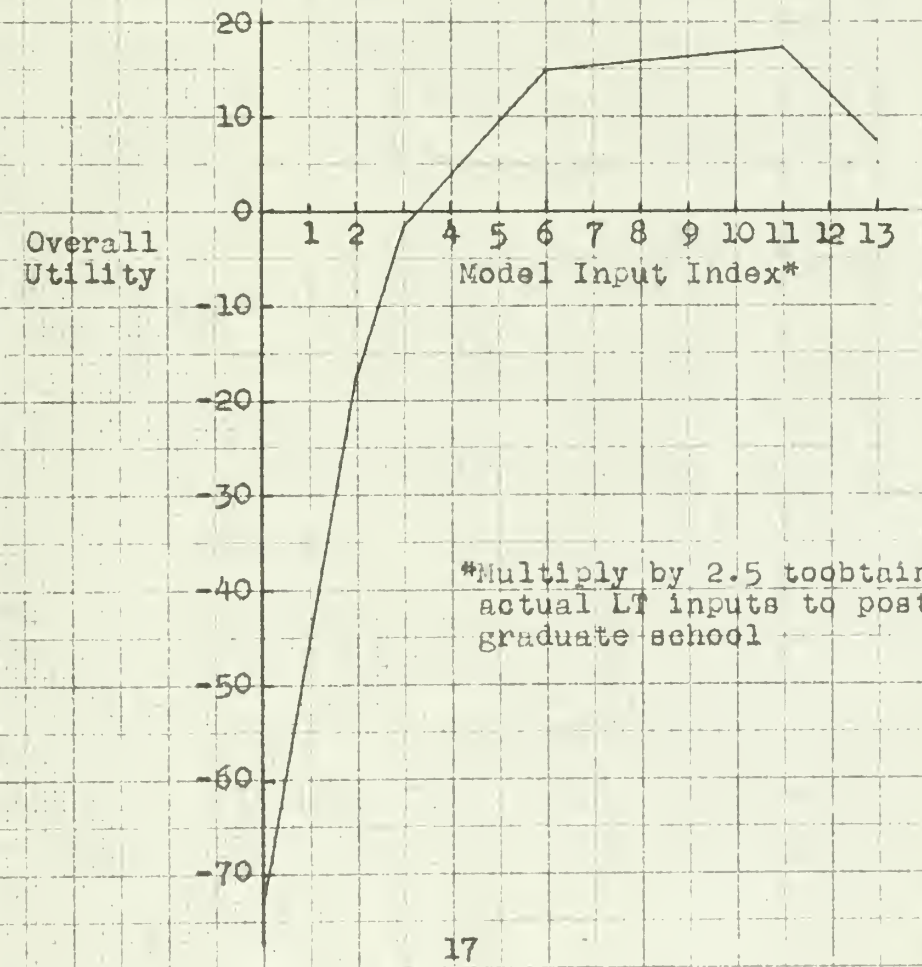
To obtain a solution from the model, let us begin by assuming that the billet requirements for graduates of a particular postgraduate curriculum are distributed as shown in the histogram of Figure 1(a). If we consider the vertical axis as a time (or rank) scale, we can consider the requirement blocks as placing demands in successive ranks on a group of postgraduate trained officers as the group progresses timewise from Lieutenant through Captain. If the number of officers in the group is smaller than the number of billet requirements in any rank, vacant billets will result as the group serves in that rank. If the group number is larger than the billet requirements in any rank, there will be a surplus of trained officers.

Figure 1

(a) Sample billet requirements for graduates of a postgraduate curriculum



(b) Graph of utility versus postgraduate school inputs



By computing the overall utility to the government generated over a career time span by various numbers of postgraduate educated officers in a group, we can determine the number of officers which results in maximum utility. Assuming negligible postgraduate school attrition, this number represents the optimum number of Lieutenant inputs to the particular curriculum under consideration.

In making computations from the model, it is convenient to assume that postgraduate educated officers serve in one duty station per rank, and that the duty is in a billet requiring sub-specialty training wherever possible. This assumption permits easier computation of overall utilities. Later we will account for time served in other duty stations by use of a scale factor. The number thus utilized as "inputs" in the model is simply an index which is proportional to the actual number of inputs in the real life situation.

In 1956 the Weakley-Daniel Board [1]

> ... concluded that the number of category 1100 and 1300 billets requiring postgraduate education must be multiplied by an availability factor of 2.5 in order to determine the minimum number of officers required to keep these billets filled.

The factor resulted from consideration of the need for these officers to perform duties at sea and in other billets; natural, academic and promotion attrition; and time lost while in a transient status. The factor 2.5 therefore

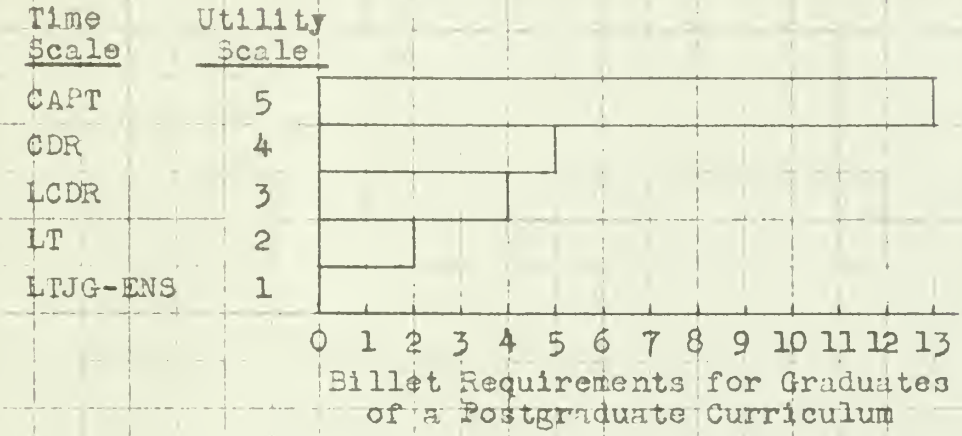
appears to be an appropriate scale factor to apply to the model input index to arrive at true officer inputs in the grade of Lieutenant.

Figure 2(b) shows a plot of overall utility versus the model input index. It may be observed that maximum utility results at a model input of 11, which corresponds to an officer input of 28 Lieutenants. What is perhaps more important to the personnel planner is that it appears that, under the assumptions of the model, there is little difference in utility to the government between a model input of 11 and a model input of six, the latter corresponding to an officer input of 15 Lieutenants. To the planner who is faced with the problem of high postgraduate educational requirements coupled with limited personnel availability, the knowledge that an annual input of 15 Lieutenants to a particular curriculum represents a "good" long range return to the government is of considerable importance. Furthermore, the utility curve indicates the relative decrease in utility as input quotas are reduced. A sample computation of overall utility for a model input index of six is illustrated in the appendix.

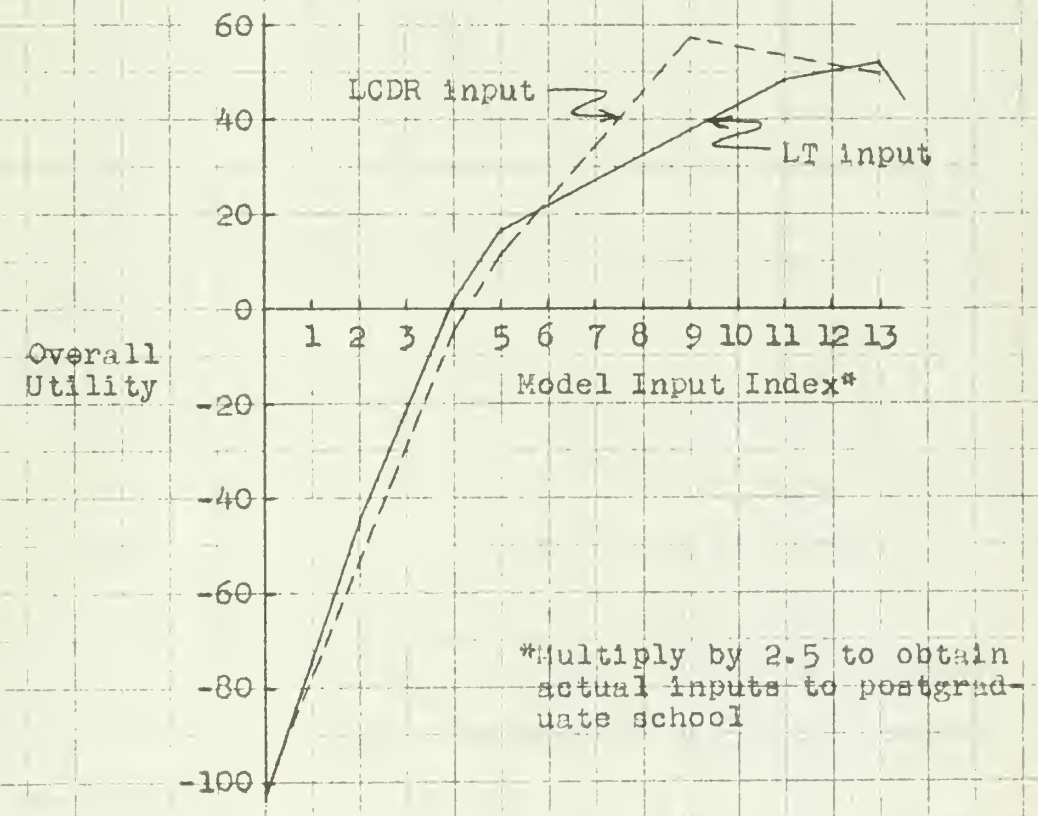
Figure 3 illustrates the situation in which the subspecialty billet requirements are "top heavy," that is, the billet requirements increase with rank. Because of the heavy weights, or utility units, assigned to the upper rank grades in this model, maximum overall utility results at a

Figure 2

(a) Sample billet requirements for graduates of a postgraduate curriculum



(b) Graph of utility versus postgraduate school inputs



model input index of 13, which corresponds to an officer input of 33 Lieutenants. Since this input appears unreasonable, a graphical plot of utility was prepared for curriculum inputs in the rank of Lieutenant Commander. This curve, shown as a dashed line in Figure 3(b), peaks at a model input index of nine, which corresponds to an officer input of 23 Lieutenant Commanders, a more reasonable solution.

The foregoing illustrations indicate some of the manipulations which may be applied to the model and the significance of some of the model solutions. The two cases selected for examination represent more or less opposite extremes in the rank distribution of billets requiring a specific postgraduate education for the incumbents. The case in which the billet requirements are approximately equal in each rank has a trivial solution. The average number of billet requirements per rank is simply multiplied by the scale factor 2.5 to obtain the optimum officer postgraduate school input in the Lieutenant grade.

The methodology employed with the model described herein may be extended to the entire spectrum of postgraduate curricula requirements once the relative importance of billets in the various sub-specialties is established. The scope of the problem would then be large enough to consider obtaining solutions through computer programming, to which the method is readily adapted.

2. Sensitivity considerations

The solution derived from the model quite naturally depends on the assumptions and parameters of the model. Of particular interest are the effects on the solution of changing the utility values over the rank requirements. For instance, if we assign an equal number of utility units to the fulfillment of a billet requirement in each rank, the utility curve shown in Figure 1(b) would have a maximum at six on the model input index. This maximum occurs at the same input index as the "good" solution using the utility function which increases with years of commissioned service. Of course, the assignment of equal utility units presupposes equal satisfaction to the government between the prospect of filling a Lieutenant sub-specialty billet with a qualified Lieutenant and the prospect of filling a similar Captain billet with a qualified Captain. In this case the model solution is relatively insensitive to small changes in the utility function.

Personnel detailing practices of necessity may result in other interesting modifications to the model. Let us consider the case where postgraduate trained officers are detailed to fill billets of the next senior rank when qualified officers in the higher rank are not available. Assume that when this does occur, the utility per billet is reduced by one utility unit from the utility function which increases in value with rank. After a bit of computation juggling, we

find that under these conditions, the utility curve of Figure 1(b) has a maximum at ten on the model input index. This is very near the index of 11 obtained originally, and indicates that the model solution in this case is relatively insensitive to the change in detailing practice. It should be mentioned, however, that the overall utility was considerably higher using this method of detailing.

The model was not thoroughly tested by comparing its solution with reasonable solutions of the real problem involving various patterns of billet-rank distributions because data was not available to the author on recent inventories of billets requiring postgraduate trained incumbents. It is very probable that with further study, the model described herein can be made more sophisticated in order to better approximate the real life situation. It is hoped that this paper, which is simply an exposition of an idea, may represent a first step in the development of a long range solution to a continuing problem.

In the event of a war which is fought over some time period, the requirements for postgraduate trained personnel would be altered. The need for various sub-specialty officers would vary with the length of the conflict, resulting in shifts of emphasis among the curricula. It is unlikely that reserve officers called to active duty could fill all of the new requirements generated by wartime operations. The problem thus presented offers an additional challenge in solving the problem presented in this paper.

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APPENDIX

SAMPLE COMPUTATION OF UTILITY

The overall utility to the government corresponding to any number of officer inputs to a postgraduate curriculum may be calculated by making use of the utility and penalty functions set forth in Chapter II. If the requirements for postgraduate trained officers were as given in Figure 1(a), the overall utilities for various model inputs would be as depicted in the graph of Figure 1(b). The following table summarizes the calculations used to locate one point on the utility curve of Figure 1(b).

Model Input: Six

	LT	LCDR	CDR	CAPT	Utility Sub-total
Billets filled	6	6	3	2	
Utility weight	2	3	4	5	
Product	12	18	12	10	52
Vacant billets	0	7	0	0	
Penalty -W	-2	-3	-4	-5	
Product	0	-21	0	0	-21
Surplus officers	0	0	3	4	
Penalty -W/2	-1	-1.5	-2	-2.5	
Product	0	0	-6	-10	-16

Overall utility = 52 - 21 - 16 = 15

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